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DAYLIGHTING RESEARCH ACTIVITIES IN THE  
ENERGY EFFICIENT BUILDINGS PROGRAM  
AT LAWRENCE BERKELEY LABORATORY

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## OBJECTIVE

To develop the technical basis for implementing daylighting strategies in new and existing buildings when such strategies promise to reduce energy consumption, reduce peak electric loads, and improve lighting quality.

## BACKGROUND

Observation in many buildings of historical interest suggests that talented builders and architects have always understood how to manipulate natural light to produce effectively daylight working environments and stimulating visual experiences. Unfortunately, these design skills are largely unpracticed by today's professional designers, who were trained in a period in which cheap electricity was the dominant light source in buildings.

A renewed concern for using energy effectively and for minimizing consumption of nonrenewable resources has reawakened interest in daylighting. The challenge for building designers is to integrate energy-related daylighting with other, often conflicting, design directions, while at the same time providing the visual performance and excitement we have come to expect from effective use of daylight.

Contrary to popular opinion, daylighting may not be the dominant energy-saving strategy in commercial building design. However, it probably will be the most important energy-related design issue because it influences building design decisions at all levels: building massing, fenestration design, lighting system design, visual and thermal comfort, and most other critical building functions. Thus effective use of daylight requires more than simply substituting daylight footcandles for electric footcandles. There may be cases where increased use of daylight increases energy consumption in a building due to additional thermal loads, or where energy savings are minimal but reductions in electric load are substantial. The ultimate decisions about such tradeoffs will be left to design professionals and their clients.

Most existing information on daylighting approaches the subject from the perspective of lighting design. If we are to use daylight effectively in commercial buildings to reduce net energy consumption and peak loads, the basis for design decisions must be expanded. Technically accurate data on daylight performance and appropriate analysis tools are a necessary prerequisite to implementing energy-efficient and cost-effective building design. In this process, it will be important to preserve the significance of daylighting from the perspective of design, visual performance, and visual quality.

Since 1976 the Windows and Daylighting Program

has grown to include not only LBL staff and facilities, but also subcontracted activities with university groups, architectural and engineering firms, private industry, and an international team of consultants. Described below are specific activities, objectives, and accomplishments in nine project areas.

## TECHNICAL ACCOMPLISHMENTS

### I. Daylight Resource Assessment

Objective: To develop a nationwide daylight availability data base that satisfies data requirements for daylighting design and energy analysis.

- For approximately three years, radiation and illumination have been recorded simultaneously at a site in San Francisco. Preliminary reduction of these data are complete, with a draft report expected in late 1981. Computer programs (SKY) based upon theoretical models have been developed and used to generate tables of availability data by latitude and to create overlays for graphic determination of daylight availability.

### II. Design Analysis

Objective: To develop a range of methods for determining the impact of daylighting as a source of interior illumination. These include graphic techniques, computational techniques, and the use of physical models.

#### 1. Graphic Techniques

- Graphic Daylighting Design Method--A graphic design method based upon the addition of daylighting contour patterns from windows and skylights has been developed. (Subcontract: University of Washington.)
- LIAM Diagrams--A set of window projections, similar to Waldram Diagrams, which allow exact determination of the sky component, including glazing losses under clear skies, for all sun positions and wall orientations.

#### 2. Computational Methods

- QUICKLITE--This simplified analysis model was written for the TI 59 calculator and computes daylight illumination at any number of points in a room under clear or overcast sky. A users manual will be published. QUICKLITE 2, now under development, will have a uniform sky model, improved internally-reflected component calculation, availability calculations, and improved input/output capabilities.
- Coefficient of Utilization Model--An improved coefficient of utilization model is under development.

It is designed to predict interior daylight illumination for complex fenestration systems, including sunlit shading devices.

- SUPERLITE--This powerful main-frame computer program is designed to calculate interior daylight illumination from virtually any aperture in any room geometry. Direct sun, external obstructions, light shelves, and simple slat-type shading systems are modeled. Further modeling capabilities are being added, and validation is in progress. (Sub-contract: University of Southern California.)

### 3. Physical Models

- Sky and Sun Simulator--A 24-foot diameter artificial sky has been constructed for model studies. It provides a uniform sky, CIE overcast sky, and several CIE clear-sky luminance distributions. A variable ground reflectance capability is being added, calibration studies are continuing, and an improved photometric system is being designed. The facility has been used for research and teaching and by architectural firms doing design studies. Several designs for indoor sun simulators are being investigated.
- Outdoor tests--Four standard test platforms on the roof of a building at LBL are used for short-term studies, primarily of shading systems, light shelves, beam sunlighting systems, and rooflighting systems.
- Scale Model/Full-Size Room Comparisons--Limited studies have been made comparing daylight measurements in an office and in a scale model of that office. The goal is to establish the level of correlation possible between measurements in models and in real environments as a function of the size and level of detail of the model.

### III. Annual Energy Calculation

Objective: To develop analytical procedures and calculation methods for determining the electrical energy savings in daylighted buildings and the net energy consumption (including thermal effects) attributable to fenestration.

- SKY 3--This computer program was developed to provide a daylighting modeling capability for DOE-2 without changing the DOE-2 program. It calculates hourly lighting schedule modifiers that represent the fraction of installed lighting power required at that hour in a given month. It is sensitive to glazing transmittance and area, shading devices, depth of daylight zone, illumination level, lighting control system, and climatic variables.
- DOE-2/DAYLITE--An improved daylighting model within DOE-2 is under development. It is designed to be flexible, both in terms of future program developments and in the range of architectural solutions that can be modeled. It will allow for a full range of sun-control solutions and for glare assessment.

### IV. Load Management and Peak Load Impacts

Objectives: To assess the potential of daylighting and associated lighting controls for load management and to determine their net impact on building

peak loads and on utility system loads.

- We have compared energy and demand costs for a 31-story office building in St. Louis and a building in San Francisco under a variety of daylighting, electric lighting, and sun-control strategies.

### V. Daylighting Controls

Objectives: To develop an improved understanding of the impact on daylighting performance of glare control, sun control, and electric lighting systems. Efforts include improving analytical models based upon laboratory and field testing of materials, components, and buildings. Results will be used in other research efforts and in improving design tools for architects and engineers.

- Glare Control--We have assessed the glare index system and defined an experimental plan to collect data that will allow us to validate the glare index for typical sky conditions in the U.S. This will help us understand what limitations, if any, glare and interior contrast gradients may place on daylighting effectiveness and user satisfaction.
- Sun Control--Computer studies using DOE-2 are underway to better define the performance characteristics of fixed and operable shading systems. Limited laboratory and field testing of these systems (venetian blinds, air-flow windows, Clearview window) have been conducted. Studies of selective transmitting coatings which admit daylight but reject solar infrared radiation are in progress. Limited exploration of optical-shutter systems has also been undertaken. Planned studies of shading systems include daylighting studies (outdoors and in the sky simulator) and testing in the Mobile Window Thermal Test (MoWITT) Facility.
- Lighting Controls--In conjunction with the LBL Lighting Research Program, studies of the performance of lighting control system are underway. Demonstrations in three office buildings have been completed, including monitoring six types of lighting control systems. Laboratory tests of the electrical and electronic performance of these systems are complete.

### VI. Commercial Building Optimization

Objectives: To determine the impact of fenestration systems on total energy use and loads in commercial buildings, and to develop guidelines for optimal use of fenestration in major classes of commercial buildings, based upon occupancy and climate.

- A model office building has been created for the first phase of this parametric study. This phase included sensitivity studies of the effects of HVAC system, perimeter-core coupling, zoning, and module size as well as parametric runs to determine the effects of glazing U-value, shading coefficient, visible transmittance, window management, and daylight utilization in different orientations and climates.

### VII. Field Measurement and Evaluation

Objective: To provide in-situ performance data (or equivalent) to validate computer models of daylighting and thermal performance of fenestration.

- Field Studies--Several retrofit office buildings have been monitored for from one to four years to determine lighting system performance and daylighting savings. We plan to extend these studies to measure performance in new buildings where daylighting was a major design factor. New instrumentation will be developed to support these activities.
- Mobile Window Thermal Test (MoWITT) Facility--This facility is designed to permit comparative measurements with high resolution of most window and skylight systems, in a simulated building context. Building conductance, air leakage, thermal mass, and internal loads can be controlled in each test cell. Instrumentation is nearing completion. The first module, having two test cells, is under construction and will undergo field calibration this winter.

#### VIII. Innovative Daylighting Strategies

Objective: To develop and characterize the performance of innovative daylighting strategies for buildings.

- For the past six years a consistent but low-level effort has been underway to characterize the performance of techniques for directing sunlight deep within buildings. We conducted extensive scale and full-size model tests of refractive and reflective sunlighting devices, with the primary emphasis on sidelighting.

#### IX. Resource Center

Objective: To make available design tools, technical data, and other information resources that will help designers implement daylighting strategies.

- Data Bases--A computerized data base system has been developed with remote access and search capabilities. Three data bases are planned: current research and personnel, bibliographic, and product data bases.
- Information Dissemination
  - a. Daylight Directory--list of researchers and consultants, publications, current events.
  - b. Instrumentation Survey--list of photometric instrument and their measurement capabilities.
  - c. Daylighting Computer Program Survey--list of daylighting computer models and capabilities.
  - d. "Windows for Energy Efficient Buildings"--newsletter for all aspects of window R & D and applications.
  - e. "Comparison Matrix of Window Thermal Barriers"--developed as a DOE insert in Sweet's Catalog.
  - f. Slide/Tape Show--a six-part, 500-slide show based upon presentations at a CCAIA daylighting workshop.
  - g. "Daylighting Bibliography 1977-1980"--a bibliography of recent literature on daylighting.
- Design Tools
  - a. Daylighting Nomographs--a set of four nomographs to assess daylighting performance and cost-effectiveness early in the design process.

- b. Availability Overlays--a set of daylight availability overlays based upon CIE algorithms was developed for the LOF sun-angle calculator.
- c. LIAM diagrams--instruction book and set of diagrams developed.
- d. QUICKLITE --programmable calculator programs, published in L.D. & A. and Solar Age; users manual being developed.
- e. Daylight Pattern Catalog--a catalog of generic daylight distributions from standard window systems under standard sky conditions, under development.
- f. Daylighting/Window Design Resource Package--a compilation of information needed for daylighting/window design. A 20-module package was planned for educators and practitioners. First draft published 8/80. Second draft of a shortened package to be published 10/81.
- Other Activities--We are organizing a three-day international conference on daylighting tentatively planned for May-June, 1982, to be co-sponsored by AIA, ASHRAE, IES, and CIE.

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#### REFERENCES

A complete list of publications by the Windows and Daylighting Program of LBL can be obtained by writing to the author at Bldg. 90/Room 3111, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720.